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AKE0001 PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:	
OKUBO ET AL.	
Serial No.: 09/993,675	Art Unit: 2829
Filed: November 27, 2001	Examiner: NGUYEN, Trung Q.
For: PROBE FOR THE PROBE CARD	

REQUEST FOR RECONSIDERATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Applicants respectfully request reconsideration of the final Office Action mailed September 12, 2003.

In that Office Action, claims 2 and 14-16 were rejected under 35 U.S.C. § 112, first paragraph, and claims 2 and 4-17 were rejected under 35 U.S.C. § 102(b) as being anticipated by Eldridge et al. (U.S. 5,974,662). To the extent that these grounds of rejection may be again asserted against the claims pending in this application, they are respectfully traversed.

Examiner Nguyen is thanked for the courtesies extended to Applicants' representative during the personal interview conducted November 5, 2003. The substance of that interview is incorporated into the following remarks.

During the interview, it became apparent that the § 112, first paragraph, rejection may have been inadvertently applied to the claims of the present application. Specifically, the

Examiner noted that the rejection was based on lack of written description. However, it was noted that pages 13 and 14 of the present application specifically describe how a probe in accordance in the present invention is manufactured. The last paragraph of page 13 states, "at first, a nickel plated fine wire for the probe" is manufactured, starting with wire material made of Paliney 7, which is then subjected to a plating process to achieve a nickel plated fine wire.

The first full paragraph on page 14 further states, "then, this nickel plated fine wire for the probe was made fine in sequence with a plurality of wire drawing dies to attain the nickel plated fine wire for the probe." The disclosed wire drawing machine is a slip-type continuous wire drawing machine, and in particular, a cone-type wet continuous wire drawing machine was used for wire drawing, along with natural diamond dies.

In view of the foregoing, Applicants respectfully submit that there is clear written description for the features recited in each of the pending claims. Moreover, in an effort to show that one skilled in the art would appreciate the wire drawing processes in connection with the present invention, applicants submit herewith descriptions of these well-known processes as applied to conventional wire drawing having nothing to do with probes consistent with the claimed invention. Specifically, the attached references are copies of portions of volumes 1, 2 and 3 of the "Steel Wire Handbook" published by the Wire Association, Inc. While the exact publication years for volumes 2 and 3 is not specifically known, volume 1 was published in 1965. Volume 2 describes wire drawing machines generally, volume 3 describes wet drawing machines such as that shown in Fig. 14-4, and volume 1 specifically describes diamond dies.

Thus, Applicants again respectfully submit that the features recited in the pending claims are supported by the present specification and would also be well understood by those skilled in the art. For at least these reasons, Applicants respectfully request that the § 112, first paragraph rejection of the claims be reconsidered and withdrawn.

With regard to the § 102(b) rejection of claims 2 and 4-17 as being anticipated by Eldridge et al., Applicants submit that this reference fails to disclose the features recited in independent claims 2 and 10. As discussed during the interview, and as set forth above, the claimed probe comprises a core material that is plated with nickel or nickel alloy. This plated core is then, or subsequently, subjected to a wire drawing operation to obtain the fine wire necessary for the inter-electrode pitch values that are necessary in connection with advanced semiconductor chip testing.

As discussed during the interview, the Eldridge et al. reference simply fails to disclose a probe having a core material made of palladium alloy or beryllium copper alloy, which is plated with nickel or nickel alloy and which is then subjected to a wire drawing operation to provide superior spring characteristics and hardness. Again, the Eldridge et al reference does not disclose performing a wire drawing operation after nickel plating or nickel alloy plating. Accordingly, Applicants respectfully submit that pending claims 2 and 10 are patentable over Eldridge et al.

In view of the foregoing, all of the claims in this case are believed to be in condition for allowance. Should the Examiner have any questions or determine that any further action is desirable to place this application in even better condition for issue, the Examiner is encouraged to telephone applicants' undersigned representative at the number listed below.

SHAW PITTMAN LLP
1650 Tysons Boulevard
McLean, VA 22102
Tel: 703/770-7645

Date: November 10, 2003

Respectfully submitted,

OKUBO ET AL.

By: ______________________
Michael A. Oblon
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(a) **Longer die life by improved lubrication and minimizing of 'tunnelling' in lubricant.**
(b) **Dies are water cooled, improving soap efficiency.**
(c) **Increased drawing speed is often possible.**
(d) **Uniform die wear, and less off-round product.**

Summary

The intricate nature of the processes involved in the manufacture of cemented tungsten carbide is not always appreciated by users of carbide dies. In recent years, the carbide die has become the standard tool of the wire drawing industry, and little thought is given by wire drawers to the continual control and vigilance which must be exercised throughout the entire process from the initial treatment of the ore, to the final sintering of the hard metal and the polishing of the die, in order to ensure the consistent high quality of the product. The carbide die is often treated in use as if it were of no more importance than the steel die which it has replaced. In actual fact, it is a highly valuable precision engineering tool which, in the hands of the skilled wire drawer, can produce results undreamed of by those who drew wire through cast iron plates in the early years of the century.

References

Many papers have been published in 'Wire and Wire Products' and other wire periodicals on the subject of dies. The following list of papers on the subject is suggested:

The Manufacture of Cemented Tungsten Carbide Dies
B. E. Berry, 'The Wire Industry', January 1952

Practical Application and Mill Practice with Carbide Dies
E. T. Miller, 'Wire & Wire Products', October 1948

Sintered Tungsten Carbide Dies in the Wire Industry
E. T. Miller, 'Wire & Wire Products', December 1960

The Design of Dies for Wire Drawing
Siebel, Ludwig & Melchior, 'The Wire Industry', April 1949

The Control of Die Profiles
J. G. Wistreich, 'The Wire Industry', February 1952

A Practical Analysis of the Cause of Die Wear in the Dry Drawing of Ferrous Wires
E. P. Riley-Gledhill, 'The Wire Industry', April 1954

DIAMOND DIES IN STEEL WIRE DRAWING

Bonzel in his book "Steel Wire" has pointed out that hard stones were used for wire dies from the dawn of wire drawing

[Ref 3]

VOL I.

equipment necessary for their upkeep. Naturally, the high cost of such tools generally limited the use of diamond dies to sizes finer than 0.040″. The introduction of the carbide die in the late 1920's created a revolution in die use in which the relatively expensive diamond die was almost eliminated in drawing steel wire, except for particular uses which will be discussed below.

Because of its great hardness — the diamond has a value of 10, the highest in Moh's scale of hardness — the diamond resists wear to an extremely high degree. Unfortunately, with its great hardness, the diamond is also extremely brittle. Care must, therefore, be taken in choosing diamonds for wire drawing; the color has no influence upon their suitability because white, grey, brown, yellow, greenish, and nearly black stones have equal utility. Pomp in his "Stahldraht" has pointed out that certain pale brown South African diamonds are unsuitable for wire drawing dies because of extreme brittleness, while fine die sizes can better be manufactured from pure yellow South West African diamonds.

Whatever stone is employed in steel wire drawing, reacceptance of the diamond die in the steel wire industry has become a question of economics; the diamond is employed in those areas where its cost can be justified in competition with tungsten or other carbides by savings in labor cost, machine output, quality, or a combination of these factors.

When are Diamonds Used?

Diamond dies are employed in steel wire drawing:

a) ***When extremely close tolerances in diameter or roundness are required*** **as, for example, in the manufacture of 0.0193″ staple wire.**

b) ***Where extremely high finish is required.*** **The resistance of the diamond to "ringing" lengthens die life.**

c) ***In the range of steel wire sizes of 0.007″ and finer.*** **It is difficult to finish carbide dies in such small sizes, giving rise to increased cost of finishing carbide dies and a corresponding reduction of the relative cost of diamonds. The overall die pressure of drawing small sizes is also relatively low, and diamond breakage is not likely in such work.**

d) ***In the range of sizes between*** **0.007″** ***and*** **0.030″ high drawing speeds result in rapid carbide wear and as speeds increase, the diamond becomes more important. It must be realized that die wear is the result of pressure between the die and *miles* of passing wire — distance past a point — rather than *tons* drawn.**

e) ***In drawing steel, and particularly in drawing stainless,*** **some elements have an affinity for the elements of tungsten carbide. If lubrication is not perfect, "galling" or "welding" will result. Such affinity does not exist in the diamond. Since World War II, there has been a**

f) *In drawing coated wires* special problems of die wear are frequently encounted when tungsten carbide is employed due in the main to the dry abrasive nature of some coatings. Some mills employ diamonds to sizes as large as 0.040"; one large mill in the United States drawing 0.032" copper coated wire determined that one diamond die lasted as long as ninety-one R-1 tungsten carbide dies at the original size. While all replacements may not be as spectacular in savings as this one, the diamond does have a use in drawing finer coated wires, and may solve carbide die wear problems in many cases.

Industrial Diamonds

An industrial diamond is defined as one unsuitable for use as a gem. Eighty-two percent of all diamonds mined fall into the "industrial" category; only a small percentage of industrial diamonds are of sufficiently high quality to qualify as stones for diamond dies for drawing steel wire. Such diamonds must be of regular shape, without twinning, and completely free from flaws and inclusions. While it is possible to draw soft non-ferrous materials through diamond dies having minor defects, steel drawing demands the ultimate in purity of stones.

The method of mounting the diamond in its metallic holder is of the greatest importance. The stone must be supported at all points or premature failure will result when drawing ferrous materials. American diamond die manufacturers have, in recent years, made great strides in obtaining better mounting of the diamond, and this has improved the value of such dies in drawing steel wire.

Die Contours Used

While practice varies from mill to mill, a basic standard in optimum contour has been developed for diamond dies for drawing ferrous wires.

a) For steel and stainless, the dies should have a primary 30° cone, well blended into a 12° reduction angle, blended into a cylindrical bearing with a length of 40 to 50% of the die diameter. The back relief is at 30°, well rounded. All work areas are highly polished. The shape of a typical die is shown in Fig. 156. Extreme variations from this standard will induce die breakage. It is unwise to vary contours of dies in the same die drawing group; dies should be selected with contours in agreement with other dies in the same set. In drawing soft metals, deviation in contour will *break the wire*; in drawing ferrous wire, deviation will *break the die*.

b) Coated steel wires require diamond dies with longer length of reduction angle than for bare wires. The bearing length, however, should be 25% to diminish frictional drag and peeling of the coating.

Maintenance of Diamonds

It is an error to think that diamond dies like carbides should

spection and recutting, if necessary, will greatly increase the overall life of diamond dies. The carbide which precedes the diamond should be checked frequently. The carbide will wear more rapidly than the diamond and, if excessively oversized wire enters the first diamond, breakage of the diamond will inevitably result.

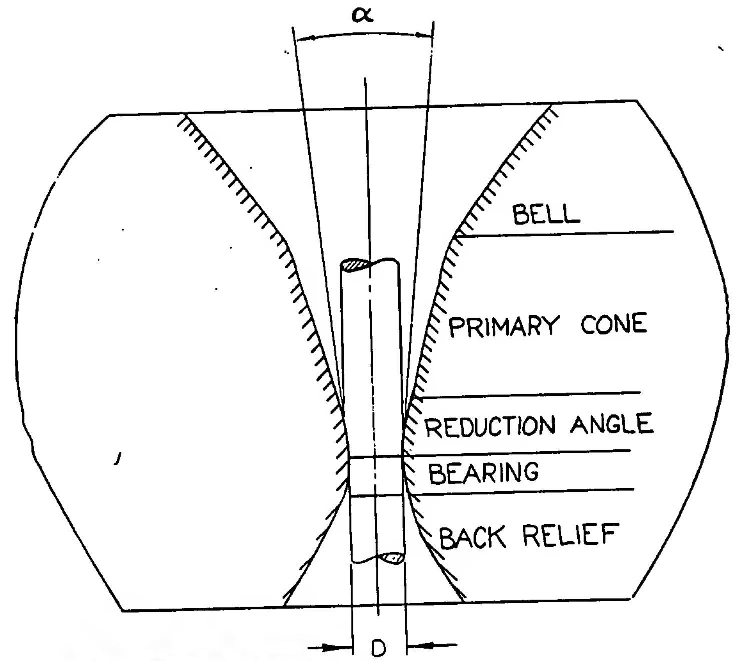


Fig. 156 — [redacted] **Note: The die angle employed in diamond dies is the total included angle of the reduction section.**

(*) THIS TYPE OF DIAMOND DIES IS APPLIED TO THIS INVENTION.

The Diamond Die of the Future

The next area of progress in the manufacture of diamond dies may be orientation of the stone to permit drilling through the hardest plane. Research by the diamond research laboratories in Johannesburg, South Africa, and testing in wire mills have indicated that by drilling the diamond in a particular manner — perpendicular to the dodecahedral plane — added amounts of wire can be drawn before excessive wear results. At the present time, however, the cost of orientation, comprising the necessity of X-raying each stone, and the flat lapping of top and bottom of

Dies for drawing **stainless steel** should have a wide approach angle, and suppliers recommend an 18° included angle with a medium bearing length. The intersection of the approach angle and the bearing should be sharp.

Dies for drawing **high carbon** spring wire and high carbon rope wire should be finished essentially the same as dies for drawing stainless steel wire with the exception that the intersection of the approach angle and bearing should be slightly blended to take away the sharpness. The approach angle should be a 12° included angle, because the draft will be less. Dies with too great a blend or a crooked bearing used for drawing high carbon wire will cause casting trouble in the drawn wire.

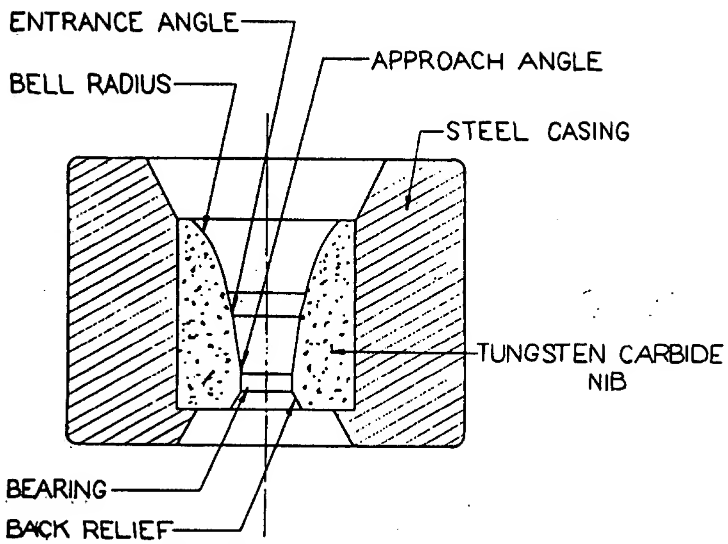


Fig. 144 — Carbide die nomenclature.

Dies used for drawing **low carbon** wire such as nail wire, coathanger wire or welding rod wire should have 16° included approach angles and medium length bearings with the intersection of the approach and bearing well blended. A sharp intersection of approach angle and bearing on dies used for drawing low carbon wire is likely to produce out-of-round wire.

Dies used for drawing **copper** wire should have 16° included approach angles well blended into a medium length bearing. If the draft is light, such as is common on shaver heads, it is advisable to increase the bearing length to a long bearing and

Dies used for drawing **aluminum** wire should have 16° included approach angles and long bearings (75 to 100% of diameter). One-third of the bearing should be blended into the approach angle until it cannot be seen where the angle ends nor where the bearing begins. The reason for this extreme blending is that the material being drawn is very soft and will not stand being drawn over any abrupt contours which may tend to cause the metal to pile up and scratch the wire. Long bearings are used in drawing aluminum wire because dies rarely wear oversize on the bearing, but do develop bad wear rings in the approach angles. The long bearing will allow the dies to be repolished several times before the bearings become too short and have to be recut to the next larger size.

TABLE IV

DATA FOR DETERMINING MEETING POINT WITH STANDARD BACK RELIEF

Included Entrance Angle	Multiply bearing length desired by factor in column applying to proper back relief. Subtract this product from the finished hole diameter. Back Relief: 90° Inc.	30° Inc.
8°	.1307	.111
10°	.1608	.132
12°	.190	.151
14°	.2185	.169
16°	.246	.184
18°	.274	.199
20°	.300	.212
22°	.326	.225
24°	.350	.237
26°	.375	248
28°	.399	.258
30°	.422	.268

NOTE: The meeting point is the hole diameter after ripping the approach angle, so that there is no bearing length. The factors in the above table apply to dies which already have back relief of the angles shown.

It will be clearly seen from these examples that, in most cases, the harder the material drawn, the sharper the line between the approach angle and the bearing; and the softer the material drawn, the greater the blend must be. Stainless steel provides an exception to the general rule.

Bearing ~~leng~~ths are generally regarded as short, medium and long. By short is meant from 0 to 20% of diameter, medium bearing lengths are from 30 to 50% of diameter, and long bearings are 75% of diameter and larger. Probably 80% of the wire

TABLE 1-3

Effects of Light versus Heavy Drafting

	Light Drafts		*Heavy Drafts*	
	0.200–0.140 5 drafts	0.200–0.060 16 drafts	0.200–0.140 2 drafts	0.200–0.060 6 drafts
Tensile, psi	82,000	115,000	87,000	128,000
Tensile, tons	36.5	51.5	39	57
Reduction of area	62%	37%	56%	29%
Bends N/r	22/.4	25/.2	20/.4	24/.2
Torsion (L = 100d)	105	40	107	43

It will be noted that in each case where the reduction was performed by light drafts, the tensile strength is lower for the same finished size. It will also be noted that the reduction of area value is lower where heavy drafts are employed in each case, but there has not been a great deal of effect on torsion value. This has assumed, of course, that when making heavy drafts the surface was not damaged since surface defects are the greatest cause of low torsional value.

REFERENCES

1. Anton Pomp (translated by C. P. Bernhoeft), *The Manufacturing and Properties of Steel Wire*, The Wire Industry, Ltd., London, 1954.
2. Maurice Bonzel (translated by K. B. Lewis), *Steel Wire*, Camelot Press, 1935.
3. H. J. Godfrey, "The Physical Properties of Steel Wire as Affected by Variation in the Drawing Operations," *Proc. A.S.T.M.*, vol. 42, 1942.
4. H. J. Godfrey, Mordica Lecture, "The Strengthening of Steel by Wire Drawing," *Wire and Wire Products, January, 1963.*
5. *The Wire Association, Inc.*, *Steel Wire Handbook*, vol. 1, Stamford, Conn., 1965.
6. H. J. Godfrey, "The Fatigue and Bending Properties of Cold Drawn Steel Wire", *Trans. A.S.M.*, March, 1941.
7. G. T. Spare, "Prestressing Wires—Stress-relaxation and Stress-corrosion Up to Date," *Wire and Wire Products*, vol. 29, December, 1954.

STEEL WIRE HANDBOOK VOLUME 2
THE WIRE ASSOCIATION INC.

Wire Drawing Machinery

The material for this chapter was supplied by Mr. J. Spearman of Vaughn Machinery Company, and Mr. R. Scott of Morgan Construction Company, with additional information by the Editor, Allan B. Dove.

THE WIRE DRAWING DIE

The prime element in drawing wire is the wire drawing die which has already been described in Vol. I. The wire drawing machine serves only to make the die effective. The wire drawing die has been aptly described as being outstanding among all mechanical devices employed by man in that it presents a very remarkable combination of simplicity and effectiveness, causing plastic flow of metal which provides elongation and reduction in diameter to a degree obtainable by no other method. It changes the physical properties of the material and provides wire with a degree of accuracy of size and section obtainable by few other methods. To the metal it imparts a dense structure, a hard surface and a high degree of polish. It becomes an automatic testing machine which detects flaws in the metals, announcing them in terms of breakage. All these functions it performs simultaneously with no other aid, apart from lubricants and coatings, than the force which will pull the material through a stationary die.

The force which makes the die effective is applied by the wire drawing machine. The same principle is employed for drawing high carbon wire, low carbon wire, stainless or non-ferrous types, but the different grades of material introduce considerable difference in design details, speed of operation and power application. Until about 1928, practically all cold drawing was carried out on wire drawing benches which consisted of a series of blocks, each capable of being operated separately from the others, with all blocks driven by a central shaft through beveled gears having cast or cut teeth, with the jaw type or friction type clutches connected to the line shaft. The central shaft was driven by a single motor and it was common to have as many as twenty blocks driven on a single shaft with an applied horsepower of up to 15 hp per block for low carbon and as high as 30 hp per block on high carbon material. Block speeds were relatively slow. Low carbon wire was frequently drawn at speeds of about 450 fpm (feet per minute) and high carbon wire at speeds in the order of 250 to 350 fpm.

Since all the blocks were driven from a central shaft by an a-c motor, speed was seldom changed between rod and finished wire size and one man was usually responsible, in rod drawing, for up to six wire drawing blocks if, for example, he were producing a four- or five-hole job. It will be appreciated that the rod was generally drawn on one block and when a coil was finished it was off-loaded onto a reel and fed to the next block in line. Because of the increasing length of the

wire, it was frequently necessary to employ two finishing blocks at the third hole or the fourth hole. Under these conditions, the man could produce about 550 lb of 13 or 14 gage wire per hour. Block frames were, in the early days, made of oaken timbers bolted together; indeed, one such frame was in use in a Canadian plant as late as 1946. The "more modern" frames of this type were steel beams and angle frames which operated from gears through clutches which started and stopped the individual blocks. Pulling devices were mounted on the sides of the machines, and generally consisted of continuous tracks into which the puller hook was inserted to start the point through the air and produce enough material to pass around the block.

As may be imagined, these early frames had very little in the way of safety equipment and it was usually necessary to depend upon the inertia of the loaded blocks to stop the machine after the motor had been shut off in case of an accident. A floor bar which served as a "snarl switch" was frequently installed between the rod flipper and the die so that a rod tangle reaching a ring on a chain attached to the bar would cause the bar to move forward; thus by mechanical linkage the block was raised off its jaw clutch which was connected to the driving gears.

Crude as the equipment may have been, however, it produced satisfactory wire for the time, and some aggressive manufacturers even equipped their benches with double decked blocks having a fixed draft between the first and second holes, special pointing devices mounted near the rod flippers, and even in a few cases with water cooled die holders when the first tungsten carbide dies came into being, and later with air cooling of the wire on the blocks. Basically, however, the unit was a simple gear-driven block which supplied the necessary force to pull the rod or wire through cast iron dies at a fixed speed with outputs largely dependent upon the dexterity of the operator.

CLASSIFICATIONS OF MODERN WIRE DRAWING MACHINES

Modern wire drawing machines may be placed in two broad classifications:

a) Single block machines, and
b) Continuous machines.

Single Block Machines

The single block machine in common use today is a vertical-spindle machine, directly connected to an electric motor and started and stopped by starting and stopping the motor. It is used on a complete range of rod sizes and is sometimes equipped with a double decked block so that two drafts may be taken simultaneously. Fig. 2-1 (a) and 2-1 (b) illustrate two makes of this popular machine and Fig. 2-1 (c) illustrates a single-deck, single-draft machine of the same general type.

This type of machine draws a range of sizes for a great many uses. It is built in

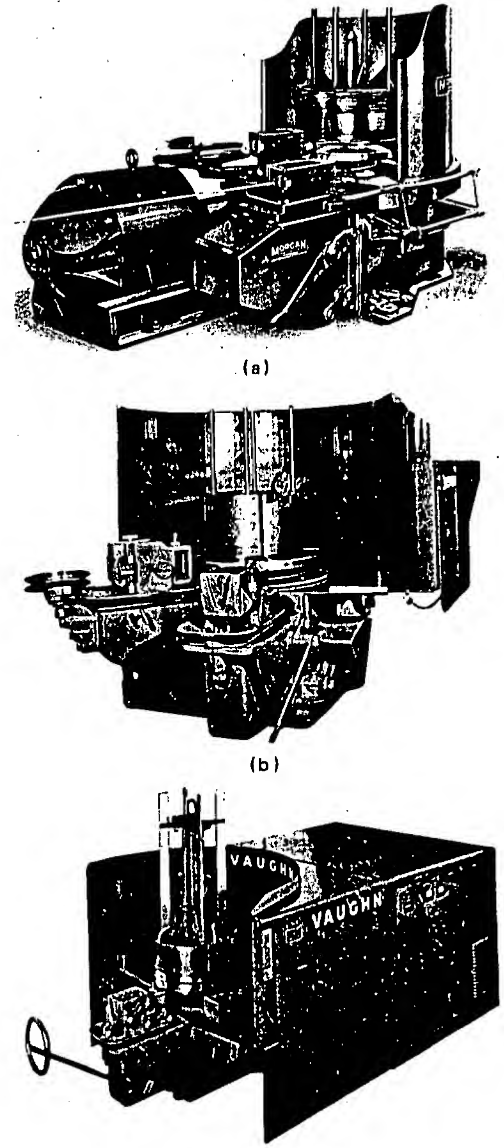


Fig. 2-1. Three examples of single block vertical-spindle machines: (a) direct-connected, double draft equipment, front motor *(Courtesty Morgan Construction Co.)*; (b) direct-connected, double draft equipment, rear d-c motor *(Courtesy Vaughn Machinery Co.)*; (c) direct-connected single-deck Motobloc (packaged) Model 15 *(Courtesy Vaughn Machinery Co.)*.

a wide range of speeds, capacities, block diameters and horsepowers. The drawing speeds may range from 100 to 200 fpm for special wire finishing, up to about 800 fpm for single draft, and from 900 to 1,200 fpm for double draft. The maximum speeds are, in general, fixed by the difficulties of unwinding or uncoiling the rods at the higher speeds. Similar machines are also built in small sizes for use on fine wire sizes which require one draft after heat treatment.

Single-block machines are also built with the block spindle in the horizontal position. On wire sizes ½ in. diameter or larger, a horizontal machine is considered superior to the vertical-spindle machine in some cases because of the ease and rapidity with which the wire can be stripped from the block. After the back end of the coil goes through the die, the recoil causes the wire to loosen all the convolutions on the block so that the wire coil is easily removed to a hairpin hook. Figure 2-2 illustrates a horizontal type block.

Table 2-1, issued by The Vaughn Machinery Co., can be employed for selection of proper heavy drawing machinery. The desired speed in feet per minute multiplied by the horsepower factor (hpf) gives the necessary drive horsepower to be employed.

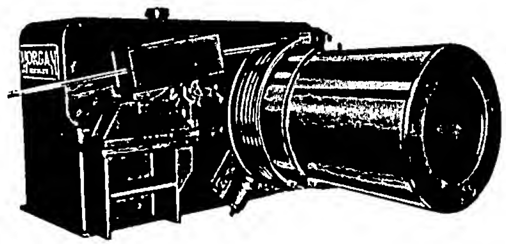


Fig. 2-2. Single block, horizontal-spindle machine, direct-connected bull block. *(Courtesy Morgan Construction Co.)*

CONTINUOUS DRAWING MACHINERY

In the early 1930s, the advent of the carbide die and major improvements in welders and welding techniques set the scene for a second major improvement; namely, continuous wire drawing machines on which more than two drafts could be carried out simultaneously. Continuous drawing machines are divided into two groups: slip type and non-slip type.

Slip Type

It has been pointed out that a search with the United States Patent Office reveals that since 1860 when wire drawing became a major industry, many attempts were made to build successful continuous wire drawing machines for steel wire. Practically all the early machines were of the "slip" type. These machines have a series of drums driven at fixed speeds with the speeds increasing

TABLE 2-1

Calculation of the Relationship Between Machine Speed and Motor Horsepower

Horsepower factor: $\frac{\text{Motor hp}}{\text{hpf}}$ = Wire fpm

for rounds 1-1/4 in. to 3/16 in.

Starting 65,000 fsi Tensile Low Carbon Steel

Fraction Start	Fraction Finish	Decimals Start	Decimals Finish	Percent Reduction	Red. area	HPF 65,000	Theo. lb per hour at 100 fpm
1-1/4	1-3/16	1.2500	1.1875	10	0.1197	0.7100	22600
1-3/16	1-1/8	1.1875	1.1250	10	0.1135	0.6710	20300
1-1/8	1-1/16	1.1250	1.0625	11	0.1074	0.6350	18075
1-3/32	1	1.09375	1.0000	16.5	0.15360	0.7560	16000
1-1/16	1	1.06250	1.0000	11.5	0.10120	0.5390	16000
1-1/32	1	1.03125	1.0000	6.0	0.04760	0.2810	16000
1-1/32	15/16	1.03125	0.9375	17.5	0.14280	0.6750	14100
1	15/16	1.00000	0.9375	12.0	0.09511	0.5240	14100
31/32	15/16	0.96875	0.9375	6.5	0.04679	0.2760	14100
31/32	7/8	0.96875	0.8750	18.0	0.13576	0.6410	12300
15/16	7/8	0.93750	0.8750	13.0	0.08897	0.4730	12300
29/32	7/8	0.90625	0.8750	7.0	0.04372	0.2580	12300
29/32	13/16	0.90625	0.8125	19.5	0.12655	0.5610	10600
7/8	13/16	0.87500	0.8125	14.0	0.08288	0.4240	10600
27/32	13/16	0.84375	0.8125	7.0	0.04065	0.2400	10600
27/32	3/4	0.84375	0.7500	21.0	0.11735	0.5200	9000
13/16	3/4	0.81250	0.7500	15.0	0.07669	0.3780	9000
25/32	3/4	0.78125	0.7500	8.0	0.03758	0.2220	9000
25/32	11/16	0.78125	0.6875	23.0	0.10815	0.5120	7570
3/4	11/16	0.75000	0.6875	16.0	0.07057	0.3480	7570
23/32	11/16	0.71875	0.6875	8.5	0.03452	0.2040	7570
23/32	5/8	0.71875	0.6250	24.0	0.09894	0.4280	6270
11/16	5/8	0.68750	0.6250	17.5	0.06442	0.3040	6270
21/32	5/8	0.65625	0.6250	9.5	0.03144	0.1860	6270
21/32	9/16	0.65625	0.5625	26.5	0.08974	0.3710	5060
5/8	9/16	0.62500	0.5625	19.0	0.05829	0.2580	5060
19/32	9/16	0.59375	0.5625	10.0	0.02838	0.1680	5060
19/32	1/2	0.59375	0.5000	29.0	0.08053	0.3170	4000
9/16	1/2	0.56250	0.5000	21.0	0.05216	0.2310	4000
17/32	1/2	0.53125	0.5000	11.5	0.02531	0.1340	4000
1/2	7/16	0.50000	0.4375	24.0	0.04608	0.2000	3060
15/32	7/16	0.46875	0.4375	13.0	0.02224	0.1180	3060
7/16	3/8	0.43750	0.3750	26.5	0.30988	0.1650	2250
13/32	3/8	0.40625	0.3750	15.0	0.01917	0.0945	2250
3/8	5/16	0.37500	0.3125	30.0	0.03375	0.1330	1560
11/32	5/16	0.34375	0.3125	16.0	0.01611	0.0793	1560
5/16	1/4	0.31250	0.2500	36.0	0.02761	0.0950	1000
9/32	1/4	0.28125	0.2500	21.0	0.01304	0.0578	1000
1/4	3/16	0.25000	0.1875	43.5	0.02148	0.0635	563
7/32	3/16	0.21875	0.1875	26.5	0.00997	0.0413	563

towards the finishing end of the machine to compensate partially for the elongation of the wire during drawing. The wire was put through a die, given a few wraps on the drum, placed through the next die, a few wraps on the next drum, and so on until the finishing block was reached. No attempt was made to synchronize the speed of the drum with the required speed of the wire. Therefore, there always had to be slip between the drum and the wire wound on the drum. The heat produced by the slippage and the consequent removal of the coating on the wire, even with block cooling, prevented this type of machine from ever being a major success on the larger wire sizes, except, perhaps, in the case of a type of machine employed by Keystone Steel & Wire Co. (Fig. 2-21). In spite of these limitations, many machines working on the principle are used today in the intermediate sizes of wire and fine wire sizes employing wet lubricants.

[redacted] Slip machines operating with wet lubricant on fine sizes of wire are known as "wet" drawing machines; these are of two types, cone or tandem. [redacted] has a series of drums or capstans mounted on the same shaft with each succeeding drum larger than the preceding one to compensate for wire elongation, and these form a cone. Figure 2-3 illustrates a cone type slip machine on which wire is being taken up on a spooler. In the tandem type, each drum or capstan is of the same diameter and each succeeding drum rotates at a specified increase in speed to compensate for wire elongation. Such a machine is typified by the Vaughn Lineblox shown at Fig. 2-22.

In the wet type machine, the lubricant and the coolant are combined in a solution of water and a soluble oil or soap compound which is pumped continuously during operating, spreading over the wire, the capstans and the dies.

Fig. 2-3. Cone type, slip, wet drawing machine with spooler. *(Courtesy Morgan Construction Co.)*

The solution is then cooled and recirculated through the machine where the cycle is repeated. In another form of machine for very fine wire, the dies, capstans or cones are totally submerged in the coolant during operation (Fig. 2-23). In these cases, the speed is dependent upon the wire size being drawn as well as the type of wire. Machines drawing very fine sizes in low carbon grades may attain speeds of 4,000 to 4,500 fpm.

Whereas some non-slip type non-accumulating machines are designed to regulate automatically the speed of one block to the next block in its line, slip type machines are essentially line-shaft driven with the reduction in area between the dies having a fixed relationship. Except for the finishing capstan, the peripheral speed of the drawing capstans is greater than the speed of the wire being drawn; hence, slipping results.

This slipping action causes greater wear on the drawing capstans than non-slip operations do. Consequently the surfaces coming into contact with the wire usually receive special attention to improve these wearing characteristics. Chrome plated high-alloy steel bands, tungsten carbide wear rings, flame plated surfaces, specialized techniques and high alloy materials are generally used.

Most slip machines are designed to provide minimum slip when the dies are selected, for example, for consecutive 20.6 percent reductions in area. Usually the drawing train provides successively decreasing slip per capstan surface as the wire passes through the machine.

Perhaps the most common type of slip machine is the type employing cone capstans. Usually the "stepped-out" or cone capstans in a machine are identical in size but are driven at different speeds so that one operates as the drawing capstan and the other as an idler capstan that merely transfers and guides the wire. The wet compound system sprays compound from the die holder directly onto the dies and bathes both capstans with copious amounts of fluid. The machine housing is oil-tight. Drawing capstans and the finishing block can be internally water-cooled.

The cone arrangement dictates that the capstans of smallest diameter receive the wire when it is thickest and that the capstans of the largest diameter receive the wire at its finest—exactly contrary to what an operator would really prefer.

In recent years, high-speed tandem machines incorporating capstans of uniform diameter throughout the drawing train and eliminating idlers have enjoyed increased popularity. The circular tandem Vaughn Ringblox is a compact arrangement requiring a minimum amount of floor space. The straight tandem Lineblox, operating on the same principles, permits somewhat easier string-up and greater variation with respect to the number of capstans built into a machine or actually used.

All slip-type machines are easily adapted to spooling and utilize a single motor drive, either d-c or a-c. While most operators prefer a central lubricating system for a number of machines, integral compound tanks are available in some instances.

Vaughn wet slip-type machinery of the HIC and HF categories are illustrated in [redacted] and general characteristics of the machines are shown in the appendix to this chapter.

Non-Slip Machines

There are in general four types of non-slip machines on the market today. These are:

a) non-accumulating
b) double-block accumulating
c) Morgan type accumulating
d) straight-through machine

Non-Accumulating Type: The wide acceptance of the vertical-spindle d-c single block machine gave rise to the logical setup of combining the individual motor principle into a machine of multiple spindles suitably geared with a tension arm between each spindle around which a loop of the wire being drawn was used to control and regulate the speed of the preceding motor by means of a "dancer" rheostat. The principle is illustrated in Fig. 2-4. Such a machine has no slip between wire and block and no twist from block to block. The first continuous machines built by the Vaughn Machinery Company were designed for low carbon wire only and for operation from a common 230-volt d-c constant potential power source. The forerunner of the modern Motoblox was air-cooled only by means of an air ring around each block along with a blast of air directed through passages within the block. It was designed for a narrow range of drawing speeds up to a maximum speed of 1,200 to 1,400 fpm. Additional cooling of the blocks was indicated when the equipment was applied to the drawing of high carbon wire; supplementing the external air cooling, internal water cooling of the blocks was added. Flange motor mounting was improved with a flexible coupling between the motor and worm shafts. As practical operating speeds, particularly for high carbon wire, continued to advance, electrical equipment became more sophisticated, thus

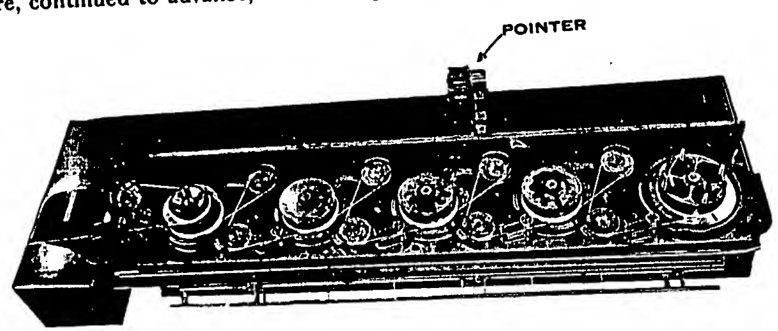


Fig. 2-4. 5/6 Motoblox threaded to show path of wire from block to block, with rear apron mounted pointer. *(Courtesy Morgan Construction Co.)*

keeping pace with mechanical improvements. Machinery flexibility in speed and product range accommodated improved substantially.

Multiple-spindle machines for continuous drawing of rod and wire are built in twelve basic versions. Although on some of the heaviest models straight-through drawing without the use of tension arms is available, most of these machines incorporate a tension arm control. They may have either horizontal or vertical spindles.

The use of adjustable speed d-c motors provides a flexibility of operation that permits the drawing of the larger sizes at the lower speeds and of the finer sizes at the higher speeds, with an infinite range of optimum speeds for the intermediate sizes falling in between. With this system, it is possible to approximate more nearly a standard tonnage production or a standard number of bundles per hour on a variety of sizes.

Each spindle is driven by an individual motor which is controlled by a tension arm actuated by the wire being drawn. A dancer rheostat or reactor is mounted in conjunction with the tension arms and controls the d-c motor speed by varying its field excitation. The machine is synchronized to draw the same number of pounds on each block without attention by the operator. The preset speed of the finishing block, therefore, automatically controls the speeds of each of the preceding spindles.

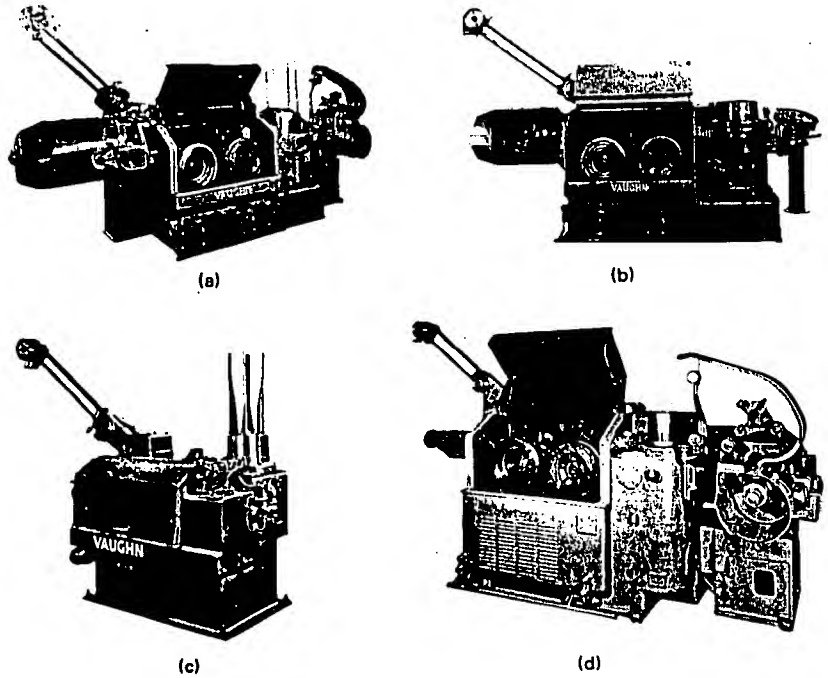
Accurate selection and maintenance of intermediate die sizes is necessary only within reasonable and practical limits. If a die opens a few thousandths, the speed at that point is automatically corrected, with the block always maintaining the same number of wraps of wire originally put on it, all without the attention of the operator.

Inasmuch as the machine functions automatically, ample time is afforded the operator to devote to welding the rod bundles together properly and to removing the finished bundle from the finishing block, thus assuring uninterrupted operation until the dies require replacement.

Slow starting and controlled threading speeds, operated by a foot treadle, permit the wire to be started through the die without serious point breakage. Once the machine has been entirely strung up, a pull of the running lever extending the full length of this machine starts the smooth acceleration of the motors to preset drawing speed automatically—without detaining the operator at the machine.

When stringing up the machine with low carbon steel wire, where the necessity of maintaining cool wire is not so important, only five or six wraps are required on each block. In the case of high carbon steels or rope wire, where the necessity of maintaining cool wire assumes much greater importance, more wraps will be required on each block in order to remove from the wire the heat generated in drawing before it enters the next die. Such practice can also be followed on low carbon wire, with some advantage in reducing intermediate block wear.

For cooling the wire during drawing, both air and water are used. At the same



[redacted](a) 12-HIC with spooler; (b) 12-HIC with flattening attachment; (c) 12 HFH with vertical-spindle finishing block; (d) 12-HF with spooling attachment. *(Courtesy Vaughn Machinery Co.)*

ANCILLARY EQUIPMENT

The operation of wire drawing equipment is dependent to a large degree upon ancillary equipment such as pointers, pay-off equipment, floor reels, snarl switches and separated takeup equipment such as spoolers and packaging devices.

Pay-Off Equipment

The refinements of wire drawing techniques in recent years, in regard to dies, compounds, cleaning and coating methods and machinery, have brought about ever-increasing finishing speeds necessitating higher practical pay-off speeds. Essentially, two basic pay-off methods are used—flipping from stationary coils and unreeling from revolving coils.

Traditionally, in steel wire mills, most flipping of rod has been done from horizontal rod flippers (see Fig. 2-10). Usually two flippers are mounted side by side about fifteen to twenty-five feet in front of the wire drawing machine. Continuity of the drawing operation is achieved by welding one complete rod bundle to the one adjacent to it and reloading bundles alternately on the empty flipper. Using this arrangement, rod coil diameters dictate flipper arrangements which, in turn, essentially prescribe machine center distances. While a distance of fifteen to twenty-five feet has been mentioned as the position point of the flippers in front of wire drawing machinery, thought should always be given to allowing as much room as possible for snarl switch operation, particularly for high speed intake. One very frequent error in wire mill design is to allow too little space ahead of the wire drawing machine so that when an attempt is made to obtain a fast intake, snarl switches do not operate quickly enough and breakage and snarling result. The decision of the placing of flippers at aisleways should always be calculated on the basis of the maximum rod or wire intake speed.

Another flipper designed to minimize over-all floor space requirements is the three-way rotating flipper (Fig. 2-11a). This unit consists of three single flippers mounted on a plate with each flipper 120° from those adjacent to it. Welding and reloading are easily accomplished and the force from the rod being drawn rotates the flipper into correct position for subsequent paying off. There are also two-way flippers of similar type available.

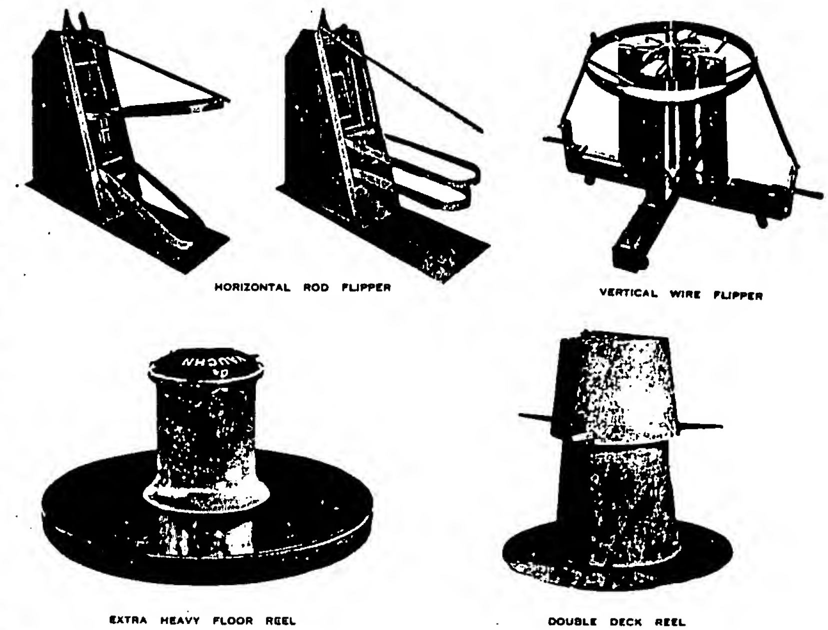


Fig. 2-10. Single horizontal and vertical flippers, floor reel and double deck reel. *(Courtesy Vaughn Machinery Co.)*

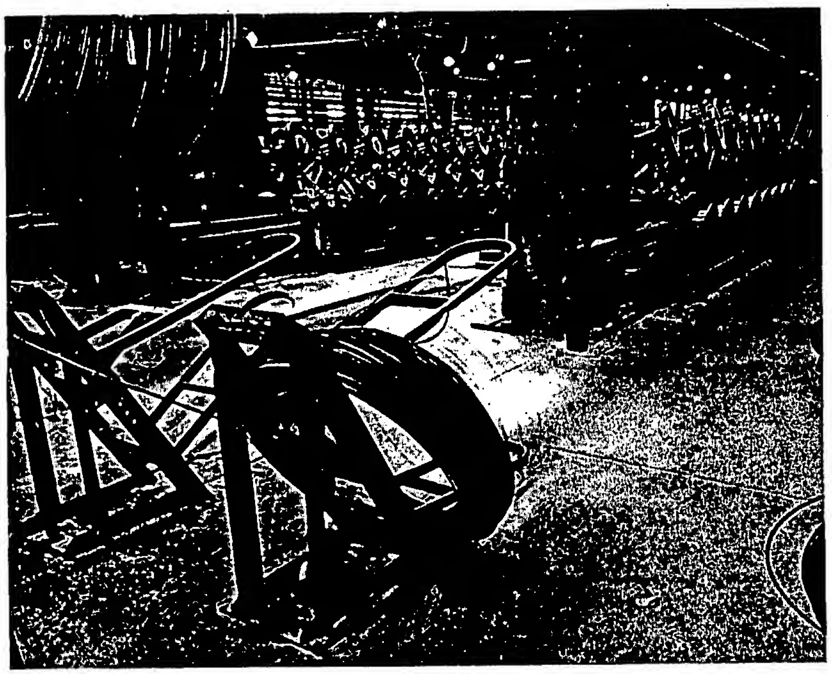


Fig. 2-21. Keystone slip type wire drawing machines. These machines are designed to operate with about 3 percent slippage of wire on each side drum. Slippage on the drums can be increased by removing one or more wire convolutions from the drum. Side drums and sheaves above are water-cooled. *(Courtesy of Keystone Steel & Wire Company)*

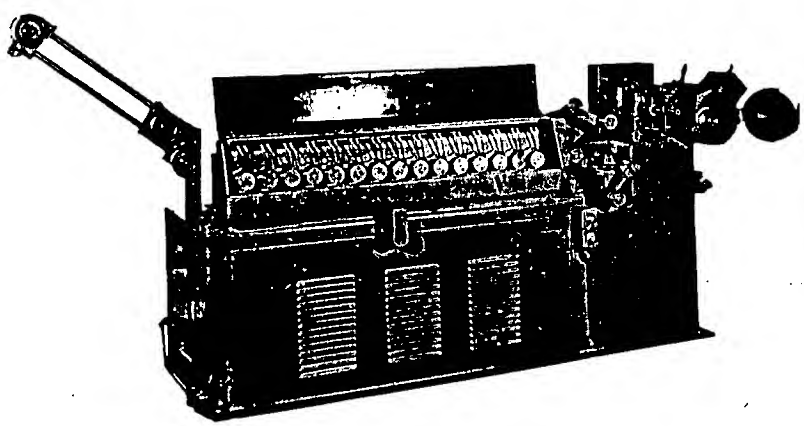


Fig. 2-22. 16-Die Lineblox. *(Courtesy The Vaughn Machinery Company)*

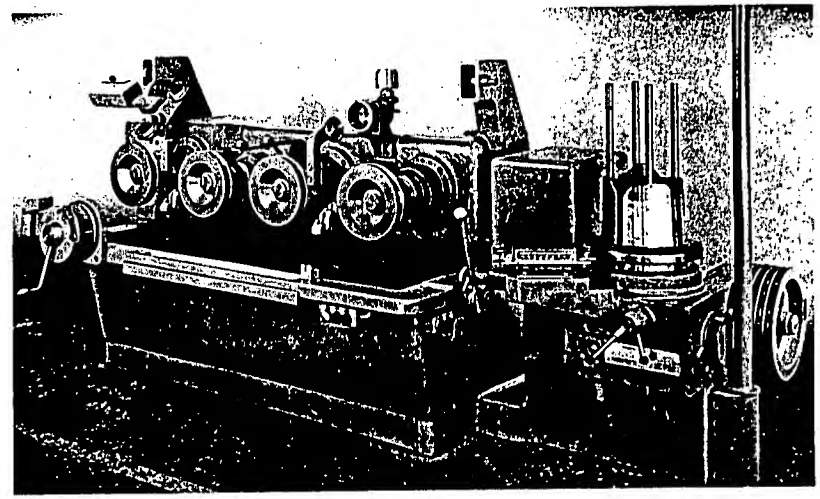


Fig. 2-23. Malmedie Type MMN III Multiple wet wire drawing machine. This machine operates with cones completely immersed in the tank of drawing and cooling lubricant. The drawing cones can be swivelled from horizontal threading position into vertical operating position by a pushbutton-operated geared motor. The machine shown here has four drawing cones and draws wire 3 mm input (0.118 in.) mild steel or 2.6 mm (.140 in.) high carbon wire. Power rating is 55 hp. *(Courtesy Malmedie & Co. Maschinenfabrik G.m.b.H., Dusseldorf)*

In the patenting operation shown in Fig. 14-2 the wire strand is continuously heated to a temperature from 1700 to 1800 F and then cooled rapidly in a molten lead bath which is maintained at a temperature between 950 and 1050 F. The high temperature removes all effects of the previous wire drawing operation, and the lead quench produces a metallurgical structure known as fine pearlite. This metallurgical condition in the wire permits further cold working.

After patenting, the wire is pickled in hydrochloric acid at room temperature to remove the scale formed during the patenting heat-treatment, and a wire drawing lubricant is applied that is sufficient to withstand a reduction from 0.120-in. diameter to 0.030-0.045-in. The amount of wire drawing is a 93.8-86.0% reduction in cross-sectional area.

Prior to a final wire drawing operation the process wire is again patented, cleaned in acid and rinsed in two water baths successively.

The wire is then brass plated electrolytically in a cyanide solution (Fig. 14-3). The purpose of the brass plating is twofold:

1. provides a surface to which rubber will adhere by vulcanizing
2. acts as a wire drawing coating

The plating time, current density and conditions of the plating bath are maintained to produce the following brass plating on the finished wire:

Copper content	—	70% ± 5
Zinc content	—	30% ± 5
Weight of coating	—	4 to 8 grams/kilogram of wire

These specifications provide the necessary thickness and composition of coating to insure the maximum adhesion to rubber. After plating, the wire is again rinsed and dipped in a special lime coating and dried.

While the first two drawing operations are "dry" drawn with a powdered soap lubricant, the final drawing operation is done "wet", Fig. 14-4. [redacted] results in a clean wire surface necessary for good adhesion of the rubber to the brass-plated tire cord. The wet wire drawing machine contains a large number of dies which may be either tungsten carbide or diamond. [redacted] are preferred because they have longer life and require less maintenance. The final total reduction in cross-section ranges from 90 to 95%. Typical final wire diameters are as follows: 0.0059, 0.0069, 0.0087, 0.0098, 0.012 and 0.015 in. When single-filament hose reinforcement wire is required this is the final operation. When strand or cord is required the wire is coiled on process spools ready for the stranding machines.

Stranding is the laying of several wires helically around a center wire. The axial distance required for a wire to make on 360° revolution around the center wire is the "length of lay" of a strand. The direction of lay may be either right-hand (Z) or left-hand (S), Fig. 14-5. Typical strand constructions for tire reinforcement are:

Construction	*Length of Lay*
1 x 3 x 0.0098 in.	0.220 in.
1 x 4 x 0.0087 in.	0.220 in.
1 x 5 x 0.0098 in.	0.240 in.

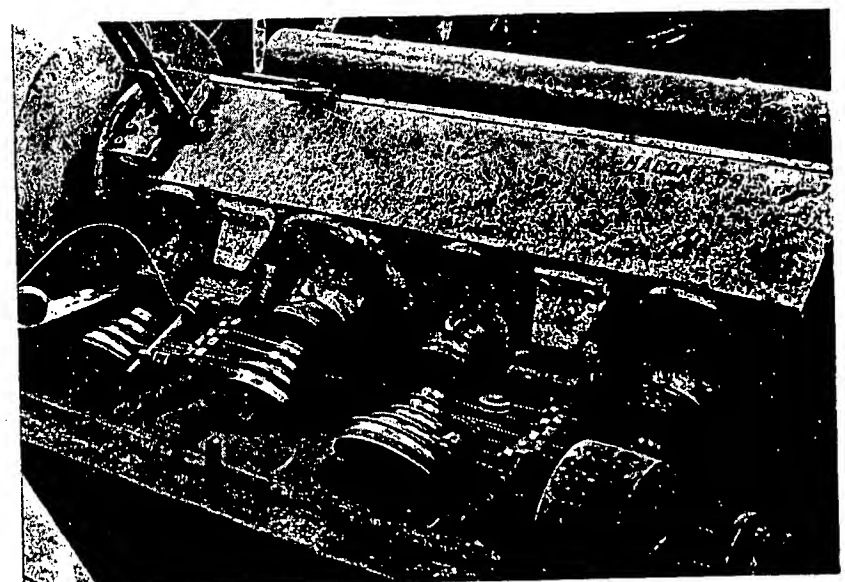


Fig. 14-4. Wet drawing machine for final sizing.